MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2015/2016

EEE2146 – MICROELECTRONIC CIRCUIT ANALYSIS AND DESIGN

(All sections / Groups)

7 MARCH 2016
9.00 a.m – 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This examination paper consists of 7 pages with 4 questions only.
2. Attempt **ALL FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Compute the transistor emitter current, I_E and emitter voltage, V_E (with respect to ground) of the circuit as shown in Figure Q1. Note that Thevenin's theorem should be used. Given that $V_{CC} = 9$ V and the transistor $V_{BE(active)} = 0.7$ V, current gain $\beta = 100$ and early voltage $V_A = \infty$.

[8 marks]

(b) Draw a low-frequency small-signal equivalent circuit of the amplifier circuit in Figure Q1 using the simplified hybrid model with transistor parameters r_π and g_m (or β). [5 marks]

(c) From the small-signal equivalent circuit, determine the input resistance R_{IN} and the voltage gain $A_V = \frac{v_o}{v_s}$. Use voltage equivalence of temperature $V_T = 26$ mV.

[12 marks]

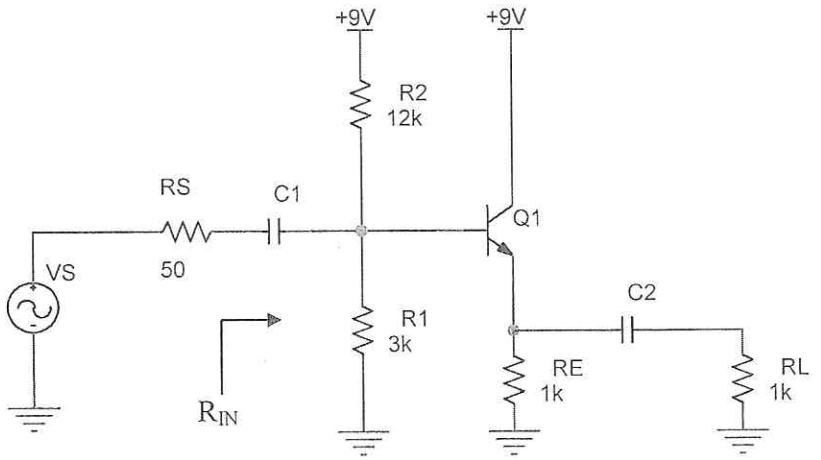

Figure Q1

Continued...

Question 2

The circuit shown in Figure Q2 is a common-source amplifier.

(a) Design the circuit so that $I_D = 2mA$ and $V_{DS} = 6$ V. Assume $V_t = 0.5$ V. Then, prove the transistor is in saturation mode.

[7 marks]

(b) Draw the small-signal equivalent circuit for the circuit shown in Figure Q2.

[5 marks]

(c) Derive and compute the small-signal voltage gain, $\frac{v_o}{v_{sig}}$, input resistance, R_{IN} and output resistance, R_O. Assume $\lambda = 0.02$ V^{-1}

[13 marks]

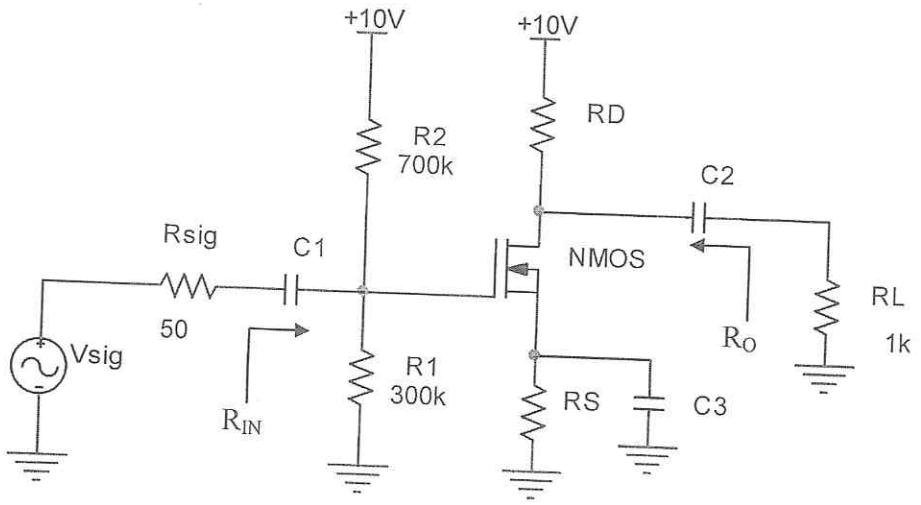

Figure Q2

Continued...

Question 3

(a) Figure Q3 (a) below shows an N-output BJT current mirror.

(i) Assume that all transistors are matched and have finite β and ignoring the effect of finite output resistance, show that,

$$I_{C1} = I_{C2} = I_{C3} = I_{CN} = \frac{I_{ref}}{1+\frac{N}{\beta}}$$ [5 marks]

(ii) Compute I_{C2} if V_{CC} = 5 V, R = 8 kΩ, $V_{BE\,(ON)}$ = 0.7 V and β = 100. [4 marks]

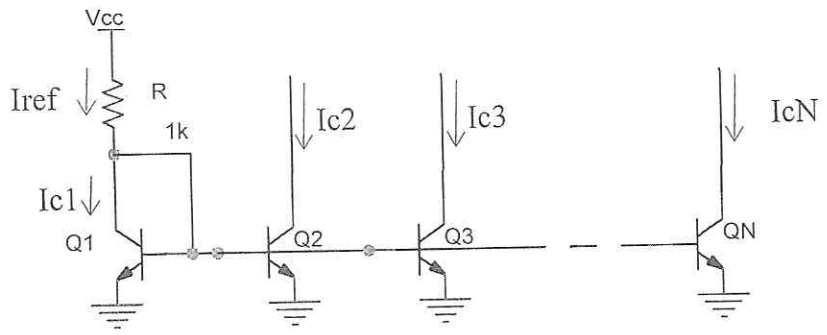

Figure Q3 (a)

(b) The circuit is Figure Q3 (b) is a basic BJT differential amplifier.

(i) With appropriate small signal equivalent circuits and by ignoring the transistor output resistance r_{ce} (i.e. r_o) , derive and prove that the small signal differential- mode and common-mode gains of the circuits are

$$A_{dm} = \frac{v_{od}}{v_{id}} = -g_m(R_C) \quad \text{and} \quad A_{cm} = \frac{v_{oc}}{v_{ic}} = \frac{-g_m R_c}{1+2g_m R_{EE}\left(1+\frac{1}{\beta}\right)}$$ [14 marks]

(ii) Then, write the equation to define the CMRR for this circuit and discuss what you should do to improve the CMRR. [2 marks]

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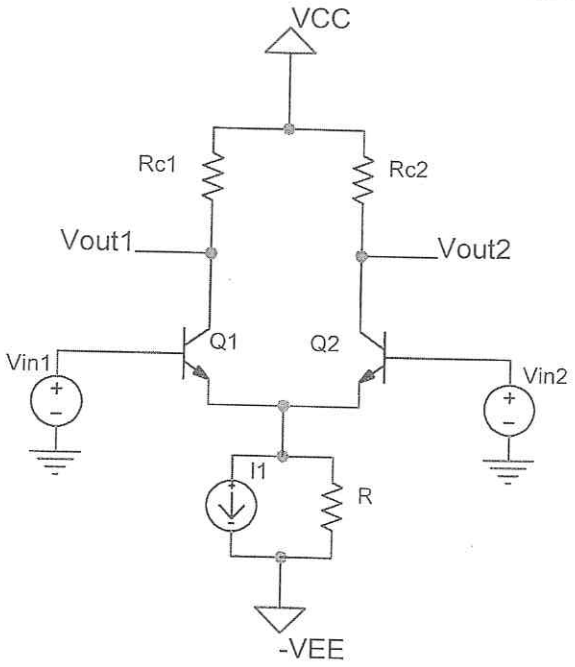

Figure Q3 (b)

Question 4

(a) Draw a low frequency small signal equivalent circuit of the circuit shown in Figure Q4 (a) using hybrid-π model with ignoring the effect of the transistor output resistance, r_o. Then, derive the equations for the lower cutoff frequencies f_{C1} and f_{C2} of the circuits. Use necessary equivalent circuits to show in your derivations.

[12 marks]

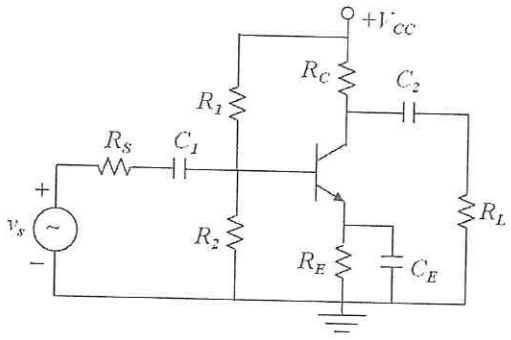

Figure Q4 (a)

Continued...

(b) The non-inverting amplifier shown in Figure Q4 (b) is a series-shunt feedback voltage amplifier. Derive the equations for gain A_f , output resistance R_{of} and input resistance R_{if}. Draw amplifier equivalent circuit to assist the derivations.

[13 marks]

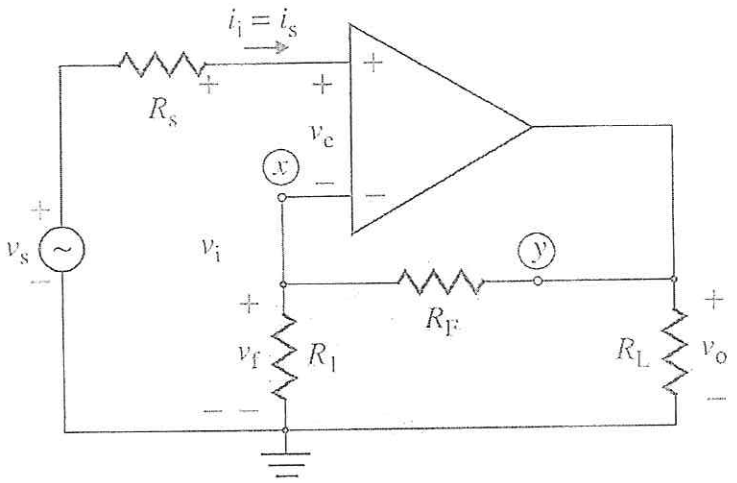

Figure Q4(b)

Continued...

Appendix: Useful formula

$$V_T = \frac{kT}{q} \approx 26mV$$

$$I_B = \frac{I_C}{\beta_F}$$

$$I_E = \frac{-I_C}{\alpha_F}$$

$$I_C = I_S\left(\exp\left(\frac{V_{BE}}{V_T}\right)-1\right)\left(1+\frac{V_{CE}}{V_A}\right)$$

$$g_m = \frac{\partial I_C}{\partial V_{BE}} = \frac{I_C}{V_T}$$

$$C_b = \tau_F g_m$$

$$r_\pi = \frac{\beta}{g_m} = \frac{\beta V_T}{I_C} = \frac{V_T}{I_B}$$

$$g_m v_\pi = \beta i_b$$

$$r_o = \frac{1}{\frac{\partial I_C}{\partial V_{CE}}} = \frac{V_A}{I_C}$$

$$r_\mu = \beta r_o$$

$V_{DS} < V_{GS} - V_t$;

$$I_D = k'\left(\frac{W}{L}\right)\left[(V_{GS}-V_t)V_{DS} - \frac{1}{2}V_{DS}^2\right]$$

$$r_{ds} = \frac{V_{DS}}{i_D}$$

$V_{DS} > V_{GS} - V_t$;

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2$$

$V_{DS} > V_{DS(SAT)}$;

$$I_D = \frac{k'}{2}\left(\frac{W}{L}\right)(V_{GS}-V_t)^2(1+\lambda V_{DS})$$

$$V_A = V_M = L_{eff}\left(\frac{dX_d}{dV_{DS}}\right)^{-1} = \frac{1}{\lambda}$$

$$r_o = \frac{V_A}{I_D}$$

$$\phi_f = \frac{kT}{q}\ln\left(\frac{N_A}{n_i}\right)$$

$$\gamma = \frac{\sqrt{2q\varepsilon N_A}}{C_{ox}}$$

$$V_t = V_{to} + \gamma\left(\sqrt{2\phi_f + V_{SB}} - \sqrt{2\phi_f}\right)$$

$$C_{ox} = \frac{\varepsilon_{ox}}{t_{ox}}$$

$$k' = \mu_n C_{ox}$$

$$V_{OV} = V_{GS} - V_t$$

$$g_m = \frac{\partial I_D}{\partial V_{GS}} = k'\frac{W}{L}V_{OV} = \frac{2I_D}{V_{OV}}$$

$$C_{gs} = C_{gd} = \frac{C_{ox}WL}{2}$$

$$g_{mb} = \frac{\partial I_D}{\partial V_{BS}}$$

$$\frac{\partial V_t}{\partial V_{BS}} = \frac{-\gamma}{2\sqrt{2\phi_f + V_{SB}}} = -\chi$$

$$\chi = \frac{C_{js}}{C_{ox}} = \frac{g_{mb}}{g_m}$$

$$f_T = \frac{1.5\mu_n}{2\pi L^2}V_{OV}$$

$$f_T = \frac{2\mu_n}{2\pi W_B^2}V_T$$

$$I_D = I_t\frac{W}{L}\exp\left(\frac{V_{OV}}{nV_T}\right)\left[1-\exp\left(\frac{-V_{DS}}{V_T}\right)\right]$$

End of Paper